Non-native Fish Removal Efforts in Grand Canyon:
A Proposed Modification to Ongoing Activities

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Executive Summary

The Grand Canyon Monitoring and Research Center, at the Direction of the Glen Canyon Dam Adaptive Management Program, began implementation of non-native fish control in the Little Colorado River (LCR) inflow area of the Colorado River in January of 2003 as part of a joint federal action entitled " Proposed Experimental Flows and Removal of Non-Native Fishes". The fisheries objective of this action was to reduce the number of potential predatory and competitor fishes in habitat occupied by the federally endangered humpback chub, *Gila cypha*. The fish control effort uses electrofishing and had three primary purposes: a) determine the efficacy of this technique to reduce and control the number of non-native fishes in critical habitat for the humpback chub, b) assess native/non-native fish interaction by conducting diet and incidence of predation studies on non-native fishes (primarily rainbow and brown trout), and c) reduce the abundance of non-native fishes in the control reach as much as practicable.

The original plan was to conduct six removal trips per year from river mile 56.2 - 65.7 during 2003 and 2004. While results regarding the diet and predation studies are incomplete at this time, it is apparent that both the efficacy of this removal technique and the reductions in abundance of non-native fish have been much more successful than anticipated. This success has prompted GCMRC to examine and propose a modification to the original plan for mechanical removal. The modification would extend the original area of removal downstream to RM 72.7, adding 7 miles to the area below the LCR. Monitoring and limited electrofishing in the original removal reach would ensure that non-native fish abundance is maintained at less than 10% of the abundance observed in January 2003. Most electrofishing and removal would be focused between river mile 65.7 and 72.7 during the fifth and sixth trips in 2003 and allocated as needed during 2004 to sustain a 90% reduction in non-natives through the entire reach (RM 56.2-72.7).

Young of the year and juvenile humpback chub (HBC) entering the mainstem from the LCR almost exclusively occupy habitat downstream of the LCR. The removal area upstream is intended largely as a buffer to reduce the likelihood of immigration downstream by non-native fishes. Extending the area of removal downstream by 7 miles could more than double the area of potentially improved habitat for young HBC. Thus the strength of this experimental treatment would be greater, increasing both the likelihood that a change in HBC survival and recruitment will occur as well as increasing our ability to detect such an increase.

This proposed modification described herein has several additional advantages and could be conducted at no increased cost from the original proposal. Furthermore, GCMRC believes that it has greater probability to increase recruitment of HBC in the near term than other actions under consideration. Advantages of this modification include reducing the amount of electrofishing that adult and juvenile HBC are subjected to in the LCR inflow area, increasing the amount of hoop net sampling for juvenile HBC throughout the removal reach, reducing the amount of scientific activity in an area of the river subject to high recreational use and concentrating that effort in fewer river miles downstream, substantially reducing the amount of scientific activity in an area of high cultural significance to Native Americans

INTRODUCTION

In December 2002, U.S. Secretary of Interior Norton approved an adaptive management experiment to be conducted in Grand Canyon National Park. This experiment, recommended by the Grand Canyon Monitoring and Research Center (GCMRC), began in January 2003 and consists of elements designed to provide a better understanding of both sediment and fisheries resources. As part of the current GCMRC Adaptive Management Program, a key objective is to determine whether certain policy actions are improving humpback chub juvenile survival and recruitment. A central part of the fisheries experiment includes reducing the abundance of non-native fishes in a 9.5-mile reach of the Colorado River near the confluence of the Little Colorado River (LCR; RM 56.2-65.7). This experimental manipulation has been implemented in an attempt to better understand interactions between native and non-native fishes, particularly non-native coldwater salmonids and the federally endangered humpback chub (HBC; Coggins et al. 2003_a, *see* attachment 1, *Piscivory by Non-Native Salmonids in the Colorado River and an Evaluation of the Efficacy of Mechanical Removal of Non-Native Salmonids*).

We proposed, and have since initiated a program to reduce non-native fishes at the LCR Inflow Removal Reach (56.2 RM - 65.7 RM). This has been accomplished through the use of a series of depletion trips where non-native fishes are captured using electro-fishing methods, euthanized, and removed from Grand Canyon for use as fertilizer. In the original proposal, our study design established upstream and downstream study boundaries based on an estimated amount of time available and human effort required. We limited the extent of our removal region downstream of the LCR to between 61.5 and 65.7 RM by taking into account 1) local trout abundance, b) electrofishing efficiency, c) immigration rates, and d) fish distribution within the channel. To date, the first three of 12-depletion trips to be conducted in 2003-2004 are complete, and preliminary analyses suggest that the abundance of rainbow (RBT) and brown trout (BNT) have been reduced by greater than 80%. This rate of reduction is much greater than anticipated following the initial phase of this effort (Figure 1). Therefore, this document describes a study modification designed to increase the magnitude of the experimental treatment by expanding the removal area downstream (i.e., just above Unkar rapid at 72.7 RM). The hope is that by expanding the magnitude of the treatment, our monitoring programs will realize a greater probability of detecting a response in humpback chub population dynamics as a result of non-native removals.

Background

Predatory and competitory interactions by non-native fishes introduced into the Colorado River system are implicated in the decline and extinction of the native fishes (Minckley *et al.* 2003, Tyus and Saunders 2000). As identified in the original proposal (Attachment 1), we recommended implementing a multi-year treatment where salmonids were mechanically removed from the Colorado River near the confluence with the LCR (LCR Inflow Removal Reach; 56.2 RM - 65.7 RM). Although the actual causal mechanism responsible for the recruitment decline in HBC remains uncertain, monitoring data has suggested that an increase in trout abundance system-wide, especially in the Colorado River near the confluence of the LCR is correlated to a recent decline in HBC abundance (Coggins *et al.* 2003_b). Therefore, the primary objective of this experimental manipulation is to assess the effect that adult rainbow trout (RBT) and brown trout (BNT) have on the population dynamics of the humpback chub (HBC) population.

Young-of-year native fish spawned in the LCR are sometimes passively dispersed or hydraulically displaced into the Colorado River mainstem. The current paradigm of recruitment dynamics of the LCR HBC population suggests that some juveniles are displaced from the LCR into the mainstem Colorado River during spring runoff and late-summer freshet events (Valdez and Ryel 1995, Robinson et al 1998, Gorman and Stone 1999, Gorman and Coggins 2000). Fish remaining in the LCR potentially have much higher survival and contribute more to annual recruitment than do displaced individuals. This downstream section below the LCR confluence is considered an important region because these young developing fish are potentially vulnerable to predatory effects from salmonids. The observed pattern is that juveniles are typically found in high abundance downstream of the LCR following an elevated LCR flow, but their abundance falls quickly in the weeks and months following the freshet (Valdez and Ryel 1995, Gorman and Coggins 2000). Additionally, the abundance of juvenile HBC declines with distance downstream of the LCR. It is possible that a high proportion of these fish fall prey to non-native predators, partially explaining this pattern in abundance and implying that negative interactions between HBC and non-natives also decline with distance downstream from the LCR confluence. We therefore originally focused our efforts in the LCR Inflow Removal Reach where native and non-native interaction is thought to be most acute.

Justification Of Modification

In the original proposal we assumed that given logistical and fiscal constraints, we would only be able to effectively reduce non-native abundance in the LCR Inflow Removal Reach. However, after the first 3 Winter-depletion trips, we are now facing the situation where we have reduced non-native abundance to the point that following the first Summer Depletion Trip (July), continued extensive electrofishing within the LCR Inflow Removal Reach to remove the few remaining non-natives may be more detrimental to native fishes than interactions with the remaining non-native fishes. This notion then begs the question of deciding what should be the effective reduction level that defines the experimental treatment. However, if we knew what the level of non-native reduction that would result in increased HBC recruitment, we would not need to conduct this experiment. Faced with this circular argument and our field observations to date, we suggest that the treatment in this experiment should be the maintenance of at least a 90% reduction in non-native abundance from the level observed preceding our first Winter Depletion Trip. We further anticipate that following our first Summer Depletion Trip (July), we will have achieved this treatment level.

With this in mind, we propose that if we have achieved our target treatment level following the first Summer Depletion Trip, we expand the treatment area to a larger river reach that encompasses more area of potential interaction between HBC and non-native fish. The extent of our removal region would be increased downstream section by an additional 7 miles to Unkar Rapid. Making our total removal reach 16.5 miles in length This is important since juvenile HBC are often dispersed beyond the present downstream boundary of our removal area. It is our contention that decreasing the abundance of non-native fishes in a larger region would increase the likelihood for greater survivorship in juvenile HBC. Additionally, we suggest that the electrofishing effort be continued as originally proposed but that the focus of the depletion effort is adjusted according to changes in trout abundance. This is important for three reasons: 1) it provides for an adaptable response to demographic shifts occurring in the local fish population, 2) allows for separate contingency plans to be in place and implemented in the event of such change, and 3) because juvenile HBC are widely dispersed, a decrease in the mortality of early life stages increases the magnitude of the treatment effect for testing the Non-native Fish Predation Hypothesis.

The scientific evaluation process used for assessing treatment response consists of two forms of measurements. The first method is to assess relative abundance among trips using both electrofishing and hoop-netting data. These data allow us to compare differences in mainstem survival of young-HBC among sampling trips, as well as survival rates among years. The sampling methods used for collecting this data provide us with the means to assess local population dynamics in response to the treatment effect at a shorter time interval. This is important because there is considerable variation in survival rates for younger fish. Secondly, since the early 1990's there has been a proportional decline in HBC age-2 recruitment of 40% to 80% based on the outcome of three different stock assessment models (i.e., Supertag, annual Age-Specific Mark-Recapture (ASMR), and monthly ASMR). Therefore, assessing the biological significance of this experiment will require some time to quantitatively measure the abundance of each year class or cohort of HBC as it recruits into the adult population. In order to detect a recruitment response and reject the null hypothesis "non-native fish predation has no affect on HBC recruitment", it is thought that an increase of age-2 recruitment to the LCR HBC population of approximately 40-50% will be required. For this reason, increasing the magnitude of the treatment effect affords scientists and managers a greater likelihood that this experiment will provide an unambiguous result to use in deciding appropriate management actions.

Risks and Uncertainties

We emphasize the importance of maximizing the treatment because of the inherent risk associated with the decision making process used in interpreting the results of this experiment. A type I error is committed if the null hypothesis being tested "non-native fish predation has no effect on HBC recruitment" is rejected, when in reality the null hypothesis is true. Although, the actual management action that would be implemented remains uncertain it is conceivable that the decision making process would result in a policy action for continuation of the non-native fish removal project or increasing this effort in other regions. The result of this Type I error would be very costly and would redirect efforts from evaluating other sources of mortality that were actually responsible for the recruitment decline in HBC. Alternately, a Type II error is committed if managers were to accept the null hypothesis "non-native fish predation has no effect on HBC recruitment" when in reality it is false, and the alternate research hypothesis "non-native fish predation has an effect on HBC recruitment" was actually true. It is conceivable that the non-native fish removal project would be curtailed. Making either of these two errors has the potential of leading to the further decline or extirpation of the HBC population in Grand Canyon.

Direct Effects on Humpback Chub from Electrofishing

We estimate that the total catch of chub using electrofishing should be slightly less within the proposed removal reach versus the current LCR Inflow Removal Reach (Table 1). This result is due to the generally lower abundance of HBC as distance from the LCR increases.

Table 1. Estimated minimum, mean, and maximum anticipated catch of humpback chub per removal trip assuming 125 hours of electrofishing per trip and recent observed catch-rate.

	Tanner to Unkar Rapids Catch		LCR Inflow Removal Reach Catch	
	HBC<200	HBC>=200	HBC<200	HBC>=200
Minimum	0	0	0	0
Mean	134	0	149	6
Maximum	457	0	1114	70

Proposed Maintenance of Target Treatment Levels

In both the original proposal and this modification, we have identified a very specific removal schedule in both time and space. These schedules reflect our anticipated results of removal activities at the current time. However, our overall goal is to reduce non-native abundance within the removal reach to 10% or less of the initial abundance (i.e. the target treatment level) for the term of the experiment, while minimizing the amount of electrofishing exposure to native fishes. Therefore and assuming this proposal is approved, we will conduct depletion estimates in both the current and proposed removal reaches during the first winter trip of 2004 (January). We will then decide whether additional winter trips are necessary and within which reach(es) in order to maintain the target treatment level. Similarly, we will conduct depletion estimates in both the current and proposed removal reaches during the first summer trip of 2004 (July) to ascertain the need for subsequent summer removal trips.

SAMPLING MODIFICATION

We would propose modifying our initial scope of work based on the sampling outcome from the scheduled July-depletion trip in the LCR-inflow Reach (56.2 RM - 65.7 RM). This general area is recognized for having the highest abundance of adult and juvenile HBC in the Colorado River mainstem (Valdez and Ryel 1995, Gorman and Coggins 2000). This modification entails expanding the linear distance of the shoreline so that it encompasses a larger geographic region downstream (65.7 RM – 72.7 RM; Figures 2 & 3). Based on previous census and monitoring studies this downstream area is recognized as a dispersal corridor as well as containing near shoreline habitat that are often utilized by small sized native fish. The proposed area increase for non-native fish removal in shoreline area represents a linear distance of 22.5-km. Therefore, we suggest that the current depletion effort continue as planned in the LCR-inflow Reach for the scheduled July depletion trip; however, that an areal expansion in depletion effort be initiated in the adjoining downstream sections during the already scheduled August and September if results from the July trip suggest that the target treatment level has been achieved in the LCR Inflow Removal Reach.

As above, initiating this modification would be contingent on the results from the overall abundance estimates and differences in catch and emigration rates between this July trip and the previous Winter-depletion effort (January-March 2003). We would initiate this modification only if non-native abundance in the initial removal reach can be kept below a target value of 10% of the January 2003 abundance following the July 2003 depletion trip. We suggest that the present sampling effort continue for the next two-years and that we alternate between depletion efforts in the LCR Inflow Reach (56.2 RM - 65.7 RM) and in the new depletion reaches. The spatial distribution of the depletion effort would be contingent on the overall abundance of non-native fishes in these proposed removal areas and changes in emigration in order to achieve and maintain target value reductions of non-native fishes in all removal reaches.

AUGUST-SEPTEMBER SAMPLING SCHEDULE

Electrofishing sampling methods

Our proposed sampling design would continue to sample using electrofishing in the established control reach (56.2 RM - 65.7 RM) measuring relative abundance and marking RBT (i.e., Floy-tags, catch and release) for determining downstream emigration rates and system-wide population changes. This sampling effort would extend for a one-night time period using four electrofishing boats. The next study element would be to conduct a single-pass depletion effort in the LCR Inflow Removal Reach (56.2 RM - 65.7 RM). This would require the use of four electrofishing boats over a two-night sampling period. Following this sampling effort, we would then move downstream to the designated depletion reaches referred to as the <u>Lava Canyon-Tanner Depletion Area</u> (65.7 RM - 68.5 RM), and <u>Tanner-Unkar Depletion Area</u> (68.5 RM – 72.7 RM).

Although these newer reaches are contiguous we have separated these into two areas based on the logistical constraints of navigating rapids during the night (Fig 1). Within these two-study areas, four depletion reaches (G – I) have been established and are consistent with the naming convention used in the original proposal (Attachment A). The depletion reaches G and H represent the respective right and left shorelines from Lava Canyon (65.7 RM) to Tanner Rapid (68.5 RM). The depletion reaches I and J represent the respective right and left shorelines from Tanner Rapid (68.5 RM) to Unkar Rapid

(72.7 RM). Each of the different reaches is to be subdivided into 500-m intervals. A series of four single-pass electrofishing depletions are to be conducted in the Lava Canyon-Tanner Depletion Area. In the Tanner-Unkar Depletion Area, we intend on moving downstream and re-establishing a base camp and repeating the same effort using four single-pass electrofishing depletions.

Hoopnet Sampling Methods

Using FWS monitoring sites (Gorman and Coggins 2000), hoopnets sampling is to be continued as a method for assessing relative abundance of HBC YOY in the Colorado River mainstem. We propose to continue sampling in the LCR-inflow Reach (56.2 RM - 65.7 RM). Following this depletion effort the trip, we would move downstream to the newly establish hoopnet sampling sites at the Lava Canyon-Tanner Depletion Area (65.7 RM - 68.5 RM) and Tanner-Unkar Depletion Area (68.5 RM - 72.7 RM). Owing to estimated catch efficiency, consideration must be given to assessing whether or not continued electrofishing will have inadvertent damage to the focus species. We recommend alternating the use of hoopnets between the Lava Canyon-Tanner Depletion Area (65.7 RM - 68.5 RM), and Tanner-Unkar Depletion Area (68.5 RM – 72.7 RM) while conducting electrofishing depletion passes in the adjoining depletion area. Findings from hoop-netting effort allow us to increase the sample size, and determine local and overall response changes (relative abundance, dispersal rates, and over-wintering survival) across multiple sampling sites.

All non-native fish stomach samples will continue to be assessed for incidence of predation, and a percentage of these samples are to be evaluated for specific diet. Additionally, drift and benthic samples will continue to be collected in upstream and downstream reaches to determine how different trout species are tracking food resources relative to their availability.

PROPOSED SAMPLING SCHEDULE MODIFICATION

Day 1	Travel day
Day 2	Electrofishing relative abundance estimates for the Control Site (43 RM – 51.5 RM)
Day 3 - 4	One single-pass electrofishing depletion for the LCR-inflow Reach (56.2 RM - 65.7 RM); drift and benthic sampling at 12 sites.
Day 4, 6, & 8	Hoopnets relative abundance estimates (3, 24-h sets) for the LCR-inflow Reach (62.4 RM - 63.5 RM)
Day 5 – 8	Multiple electrofishing depletion passes (4 Nights), Lava Canyon-Tanner Reach (65.7 RM - 68.5 RM); drift and benthic sampling at 12 sites.
Day 5, 7, & 9	Hoopnets relative abundance estimates (3, 24-h sets) for the Tanner-Unkar Reach
Day 9 – 12	Multiple electrofishing depletion passes (5 Nights), Tanner-Unkar Reach (68.5 RM – 72.5 RM); drift and benthic sampling at 12 sites.
Day 10 - 12	Hoopnets relative abundance estimates (3, 24-h sets) for the Lava Canyon-Tanner Reach
Day 13	Reorganize gear, supplies and equipment.
Day 14	Technicians hike out
Day 14 - 17	Runout/takeout (Diamond Creek)

SUMMARY OF WINTER TRIP DEPLETION ACTIVITIES

Examination of the preliminary results from the January, February, and March Removal activities suggests a reduction ~87 % in RBT from the initial January abundance (6,498 fish) following the March trip (782 fish; Figure 1). Theses analyses also indicate very little change in the abundance of RBT between the end of the January trip and the beginning of the February trip (~ 61 fish). However, there was an apparent much larger change in the abundance of fish between the end of the February trip and the beginning of the March. This apparent change in abundance is not unusual even in closed system depletion efforts and could therefore be explained either by immigration into the removal reach, or fish that were previously invulnerable to the sampling gear during January and

February becoming vulnerable during March. Further sampling during the removal efforts in July should allow discrimination between these competing hypotheses. Monitoring by the Arizona Game and Fish Department during April indicates the abundance of fish in the removal reach was approximately 80% of estimates obtained the previously year. This observation adds further credibility to the notion that rapid large-scale immigration into the removal reach is not occurring.

It is our hope that this proposed modification to the existing proposal (Coggins *et al.* 2003) is acceptable and that the concerted effort identified herein be maintained in order to accomplish the stated objectives of this experiment.

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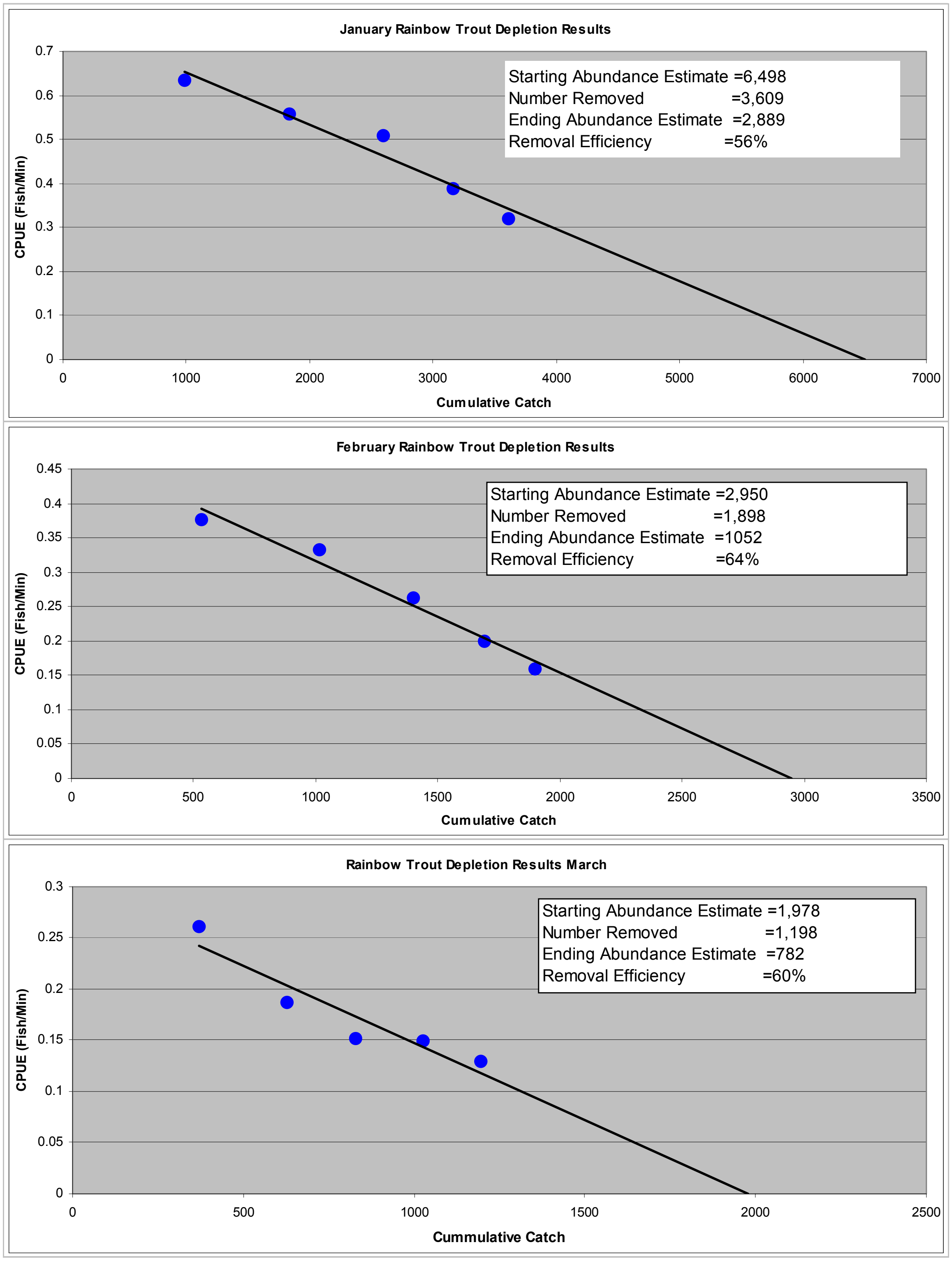

Figure 1. PRELIMINARY ANALYSES. Estimated abundance using the Leslie Method (Leslie and Davis, 1939) at the beginning and end of the three winter non-native depletion trips. The interceptions with the x-axes (cumulative catch) represents the abundance estimate at the beginning of the trips.

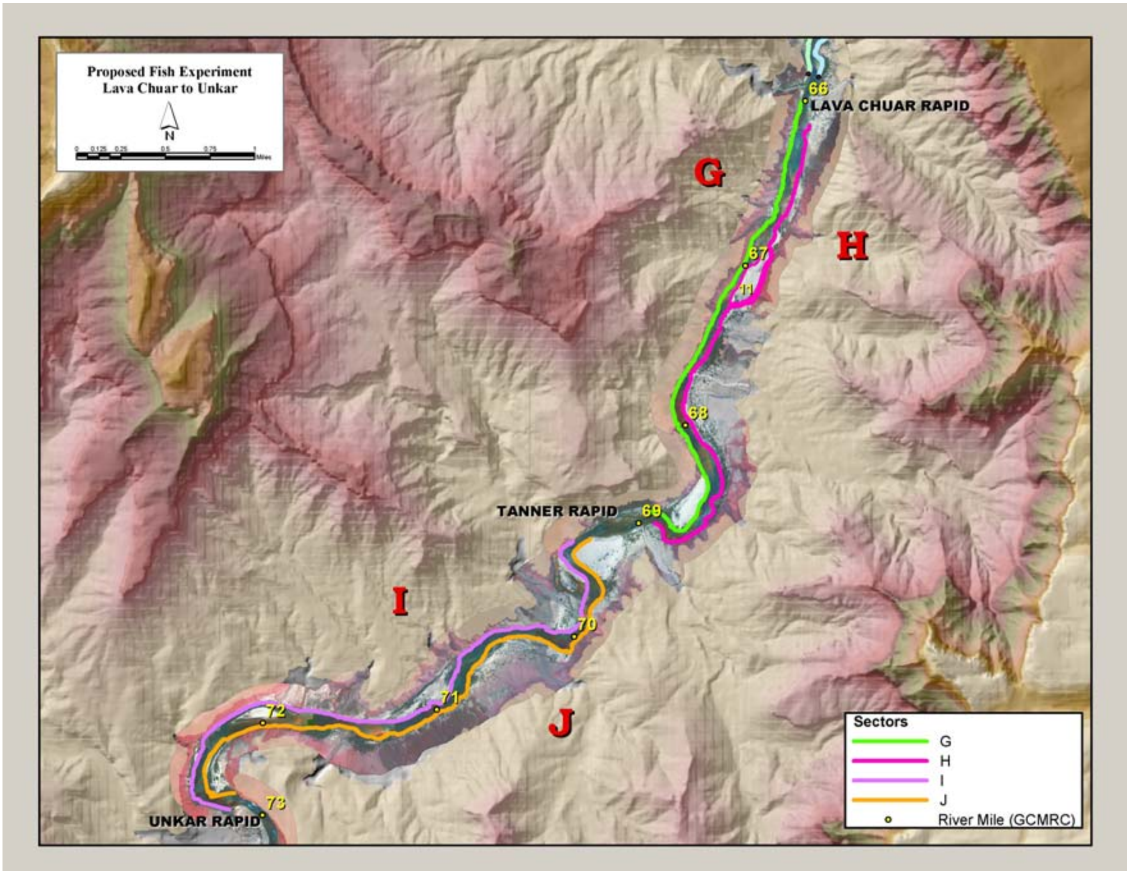

Figure 2. Map of the Colorado River depicting proposed removal reaches.

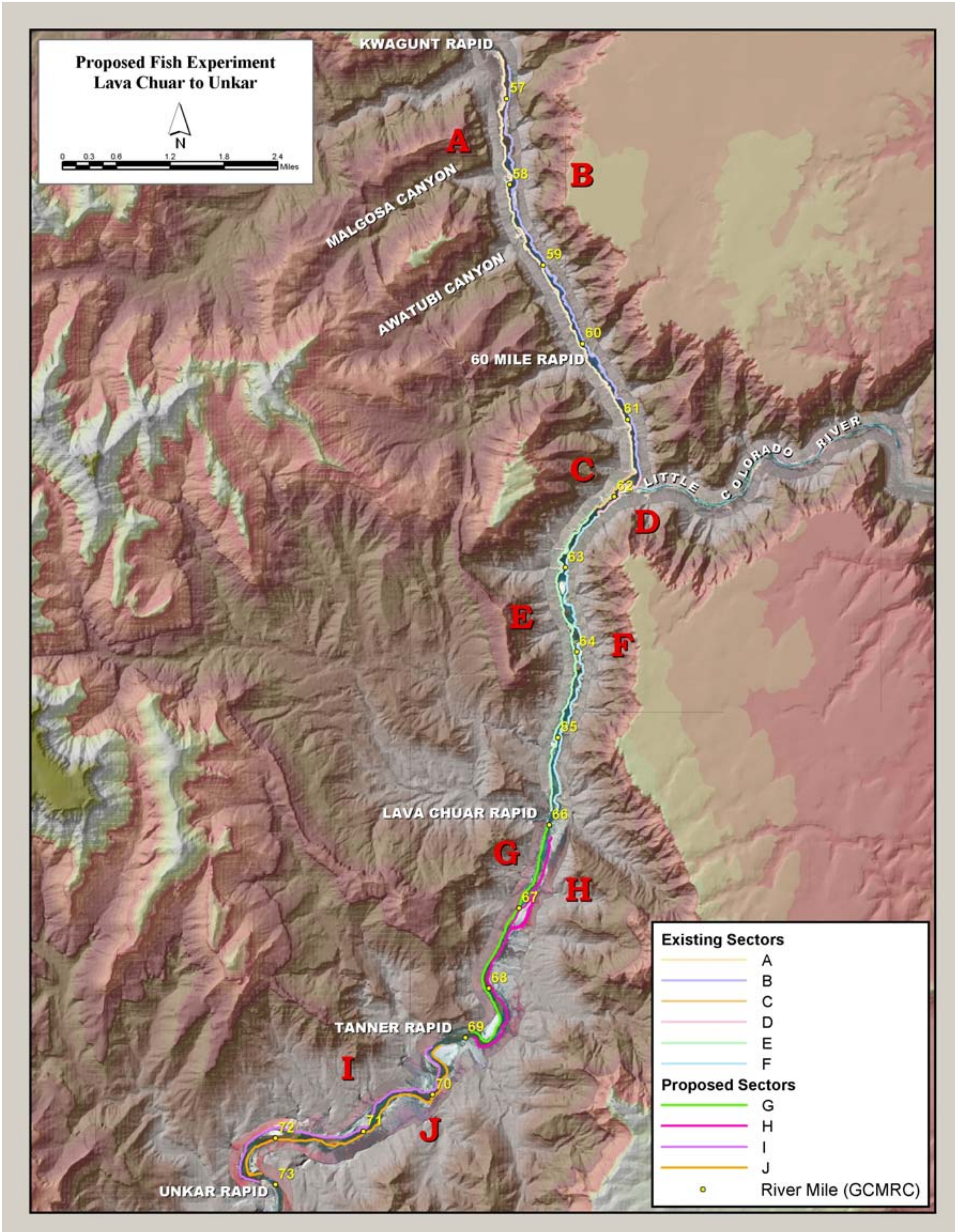

Figure 3. Map of the Colorado River depicting existing and proposed removal reaches.